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AUTHOR Follettie, Joseph F.
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Joseph F. Follettie

The recent round of social projections to the year 2000 and beyond yields forecasts that appear already dated. Accurate social prognostication is hampered by the fact that what could occur is seldom inevitable. To extrapolate from available trends to future forms is simply to enumerate the possible social architectures that a developing technology provides as options.

The leading edge of the state-of-the-art no longer looms as transcendental to defining the future because it is no longer apparent that the momentum of gadgetry alone can carry humanity safely across another generation of time. Whether the year 2000 will be characterized by the ultrasonic toilet or the privy cannot be determined solely on the basis of technological trends. Forecasts of future social architectures, then, can be no better than an underlying divination of the functions that a future society will find compelling. This is no less true for education than for housing, transportation, or commerce.

The task of forecasting a future architecture is eased if the treatment of a broad range of social functions gives way to the treatment of a more-restrained scope. It is eased further if the target era is brought nearer to the present. However, even then it remains a perilous business to forecast the future from the vantage point of a neutral observation platform. Benign forecasts concerning educational functions and architecture in the 1980-1985 era are only relatively less risky than forecasts addressing a larger domain at a later time.

The benign observer of trends can only review new possibilities much as a salesman reviews a product line. One who would preview the future rather than review its possible forms has no recourse but to abandon the neutral observation platform. While there is no assured route to a previewed future, any wish to move toward a specified future will be better served by an active pursuit of that future than by a benign contemplation of it as one--however desirable--of several alternatives. This is the sense in which Boguslaw (1965) refers to system designers as new utopians.

The old utopians spoke only for themselves and their more-committed disciples. System designers will prove equally ineffectual unless their perspective is broader. We cannot say today with great assurance just what functions a society will require an educational system to execute in the 1980-85 era that this paper takes as an upper bound to the system design effort. Not all of the skills that currently underlie effective functioning in young adult roles will have *educational relevance* when judged against the young adult roles that society defines in 1985. However, it is useful guidance to the educational system designer that a skills domain must be kept under continuing surveillance and redesigned to be consonant with the changing requirements of society. A changing social climate may levy changing views of educational relevance on the system designer. In consequence, the notion that educational system designs will need be congruent with skills requirements defined on changing young adult roles seems inevitable throughout the period of interest.

If a relevance analysis compels that a specified mastery level be attained for a given skill, then *educational effectiveness* is established for any instructional treatment that secures the objective. Any instruction that is effective specifies a sufficiency set of conditions that, met, insures that the objective will be attained. Effective instruction simply accomplishes what it is asked to accomplish. A second constraint placed upon the educational system designer then is that the system produced yield effective instruction. Warrantably, a changing society will be unchanging in its demand that instruction be effective.

Instruction that is relevant and effective yet may be inefficient. Effective instruction can take various forms reflecting different levels of *educational efficiency*. Since effective instruction must meet only sufficiency criteria, given effective instruction may negotiate a longer route to its objectives--and so be costlier in instructional time and other resources--than instruction required to meet necessity-sufficiency criteria. A third constraint placed on the educational system designer is to produce a system that yields instruction whose efficiency is state-of-the-art optimal. Warrantably, a changing society will be unchanging in its demand that instruction be as efficient as exploitation of the prevailing technical state-of-the-art can make it.

The educational system designer seeks actively to design and so constrain the form of future educational systems, rather than to simply make forecasts based on technical possibilities. This effort is constrained by requirements that the educational system be compatible with the work that society wants done and that, when doing such work, it perform effectively and efficiently. The forward orientation of an educational system design effort has the same sort of origins that cause other complex systems to be designed well ahead of product utilization. An educational system now comprehensively blueprinted to exploit the pertinent efficiency state-of-the-art would be sufficiently complex to condition installation of the system upon a large effort made over an extended period. Moreover, to the extent that the generic pedagogical notion of interactive instruction has merit, one can perceive the outlines of future educational systems that promise to be much more efficient than the prevailing state-of-the-art will allow, but which cannot be comprehensively blueprinted pursuant to production until scientific and technical state-of-the-art are pushed in suitable directions. If we do not begin today to formulate in preliminary sketchy form these potential educational systems of the future, the chances are poorer that the prerequisite scientific and technical advances underlying production of these systems will occur than if these systems are left unsketched.

Parker & Dunn (1972) make the case that cable television will be available to a preponderance of Americans a dozen years hence. Whether cable television will serve as an expanded amusement opiate of a people already more amused than enlightened, as an additional handle to self-service brainwashing, or as an effective instrument for early and continuing education depends more on today's vision than on tomorrow's. The television terminal that an amusement-oriented industry would provide the user of cable television is far from isomorphic with the terminal that an orientation to education would compel. A laissez-faire attitude toward cable television is opting for more amusement opiation--for an apathetic culture that few lobby for but that we will get by default if the customary taste-makers are allowed to make their dollar according to the law of least resistance. In consequence, we draw the moral that the educational system designer will behave like the benign prognosticator in one respect. Both will enumerate the scientific and technical options that current trends portend. However, the system designer will do this to serve the present rather than the future. His objectives will be to establish state-of-the-art and to suggest directions in which state-of-the-art should be pushed to insure a) that the educational enterprise gets its fair share of the market and b) that it serves its market on the most productive basis that can be achieved. The educational system designer will plan ahead because the only alternative is to plan behind.

TRENDS AND POSSIBILITIES

The prevailing educational system(s) and perceivable potential alternatives can be analyzed within a scheme of rubrics that should apply equally well to alternative formulations, both now and later. Any system is conceptually a functioning architecture. For present purposes, it suffices to characterize the functions of an educational system generally as production of relevant, effective, and efficient instruction. The architecture that will insure such functioning has three general components. An instructional component--herein denoted a *pedagogical architecture*--specifies what will be taught and how it will be taught consonant with effectiveness-efficiency criteria.

Theoretical effectiveness-efficiency of the system--that which it has in principle--is written into its pedagogical architecture. We might say, then, that the functions of a pedagogical architecture are to secure in principle the functions that motivate and propel the educational system. A delivery-interactive component--herein denoted an *information architecture*--specifies the means whereby the pedagogical architecture will be brought to bear on pupils to achieve system functions. The functions of an information architecture are to secure in practice the functions that a pedagogical architecture secures in principle. Finally, a *site architecture* specifies the address or addresses at which the information architecture will cause the pedagogical architecture to impact upon pupils and the address background conditions under which instructional acts will be consummated. Trends and possibilities are sketched below on a rubric-by-rubric basis.

Pedagogical Architecture

Education during antiquity took tutorial form. Either the tutor taught the pupil to read and write in Latin, to cipher, and to use weapons or the master did not pay. In this economically intimate situation, there was little point in placing the failure monkey on the pupil's back--where no doubt it sometimes belonged. Hard cash considerations compelled that instruction be effective and somewhat efficient; appeals to incorrigible oafishness in the pupil could only signify untenability, and so dissolution, of the contract. There was no money to be made from teaching pupils to obtain failing grades. While history does not reveal the proficiency testing rationale in technical detail, it appears warranted that tests were criterion-referenced, that criterion levels were set stringently high, and that skills mastery was defined on longer-term, or more-permanent, effects. Granting that education reached only the sons of the privileged, the prepsychometric era of tutorial instruction gave society free market education at its best.

Mass education of the many replaced tutorial education of the few a century or so ago. The nobility of its objectives notwithstanding, mass education necessarily destroyed much of that intimate teacher-client relationship that conditioned the successes of a laissez-faire approach. Suddenly the teacher was working for the state--a more remote and hence much easier client to bamboozle. The tutorial cell and the independent one-room school gave way to collections of multiroom schools yoked together by networks of education administrators. Given the license that a laissez-faire milieu extends to all entrepreneurs operating under indifferent or naive sponsorship, mass education personnel followed the course of least resistance. They invented the norm-referenced proficiency test--the basis for transforming education into a sort of two-person zero-sum game that educators could not lose. Whereas the teacher in a tutorial context was required to produce or fail, the teacher in a mass context was required only to keep house and, on occasion, to scale the pupils of a class for degree of educational incorrigibility. With technical assistance from classical psychometrics (increasingly from the time of Galton), educators succeeded in placing the failure monkey on the pupil's back. While few would care to admit that psychometric evaluation compels invalidation of the proposition that teachers teach, that is largely the case; under such a rationale, learners learn or fail to learn; those who fail to learn are educationally incorrigible.

In a society increasingly predisposed to organize an electorate according to cost-return benefits, norm-referenced proficiency testing at last has become as politically untenable as it has been from the outset pedagogically untenable. Hence, there is a growing trend--or predisposition at least--toward criterion-referenced proficiency testing in the context of appropriate views regarding the conditions under which a skill will be assumed mastered. Criterion-referenced proficiency tests tend to employ items to be responded to or problems to be solved that are more apt to evaluation of referenced skills than those used in norm-referenced tests. However, item-problem aptness is not the central feature distinguishing the two types of test. These tests are centrally distinguished on the basis of how used. The norm-referenced test is used to distribute individuals for comparative purposes. This can either be done on an absolute basis that has some overtones of criterion-referencing--as when a score of 95% correct responses is required for an A and a score below 75% signifies failure--or on a purely relative basis--called grading on a curve. Conversely, the criterion-referenced test is used to evaluate pupil proficiency per se. Either the pupil does or does not achieve a criterion proficiency level when tested under suitable mastery conditions. If he does, then he advances to new instruction addressing a new skill or integrating two or more already-mastered skills or subskills. Pupils do not fail in the sense of learning little or nothing. However, a given expenditure of instructional time will result in some pupils mastering an appreciable skills domain while other pupils are mastering a more modest skills domain.

The unavoidable implication of a commitment to criterion-referenced proficiency tests is that failure to reach criterion on a test must compel some form of supplemental instruction whose effect is to cause the pupil now to reach criterion. Such an instructional response--often called remedial instruction although that term has undesirable connotations when taken literally--must have occurred routinely during the tutorial era preceding mass education. However, effecting such responses in the one teacher-25 pupil classroom, if possible, cannot be accomplished routinely. The trend, in educational system design circles, is to attack this problem in a way that insures that the one-many administrative format of current education does not get in the way of the tutorial requirement of matching the instruction to the needs of the individual pupil.

Part of the problem concerning how aptly to exploit the criterion-referenced proficiency test in mass education settings is pedagogical and so references to a pedagogical system. The rest of the problem belongs to those responsible for architecting the information system. We consider only the pedagogical portion of the problem here; the informational portion is taken up in the next section.

If a pupil fails to reach criterion on an appropriate proficiency test following specified initial instruction, the failure may characterize all elements or subskills of the skills domain addressed by initial instruction or only one or a few such elements or subskills. It is a task of the pedagogical architect to explicate the structure of the skills domain, to devise a proficiency test instrument that reflects this structure and its elements, to define a rationale for inferring whether failure is general or restricted to a particular region of the structure--often called a diagnostic rationale, and to specify the form of supplemental instruction addressing remediation of failure--often called prescription. The current trend in educational system design is to explicate and build into the pedagogical architecture this system of responses to a failure-remediation function of the architecture.

Children come to given instruction differently equipped regarding what could be taken as a suitable "data language" of instruction. Any attempt to ground the instruction on a "universally-understood data language" probably would bore some pupils at the expense of providing sufficient explication for others. Similar possibilities occur for processing surface grammatical structures. Some children will enter given instruction equipped to handle more-complex structures than will others. The pedagogical architecture must cope with such differential tendencies, whether these simply reference to entry performances or extend also to more-permanent manifestations--e.g., regarding rate of advance referenced to given skills. Differential pupil requirements concerning form and explication can be handled at the level of initial instruction, supplemental instruction, or both. At the level of initial instruction, a responsive pedagogical architecture would condition form and explication of the instructional treatment on results of entry-level proficiency tests. At the level of supplemental instruction, the experience provided by initial instruction and a criterion proficiency test administration permit pedagogical architecture to be responsive to the individual pupil's predisposition regarding instructional rate and to the particular regions in which supplemental instruction is required. Although much light remains to be shed on factors that are crucial to suiting the instruction to pupil characteristics, it is apparent that doing so falls in the province of pedagogical architecture. That is, the architect of pedagogical systems will need to insure that the pedagogical architecture is responsive to pup[illegible]eristics, which it will be if it defines suitable instructional alternatives referenced to such characteristics.

Any tendency to individualize instruction consonant with provisions of a criterion-referenced testing rationale must institutionalize the proposition that some pupils will master a wider skills domain by age 18 or an alternative cut-off point than will some other pupils. Assuming for present expository purposes that entry into young adult roles will more or less be defined on chronological age and that no educational system ever will overcome a tendency for some individuals to master a wider skills domain per unit instructional time than will some others, one approach open to the architect of pedagogical systems is to distinguish between a *mainline* skills domain that is consonant with the definition of relevant education that a given society compels and an *elective* skills domain that goes beyond the skills that are inherent in the practice of effective young adulthood. This approach at once serves the apparent realities and the growing humanist insistence on giving the individual a wider range of choices concerning the domains in which he will become skilled or conversant. Reading and calculating to certain mastery levels clearly belong to the mainline. However, the reading of engineering manuals and scholarly treatises whose comprehension is a matter of special rather than general concern and the calculations inherent in higher forms of mathematics seem much less crucial to finding one's way across the domain of young adult roles. The time of all children should divide between mainline and elective skills instruction in the schooling situation. Children leaving school at age 18 then would tend to be quite similar for mastery of skills of the mainline domain, but would vary appreciably in number and types of skills mastered or appreciated in the elective skills domain. Providing elective skills and sequencing them relative to mainline instruction also is a responsibility of the architect of pedagogical systems.

While criterion-referenced testing perspective compels the mastery of certain mainline skills as a precondition to advance to new mainline instruction, whether this perspective should be extended to elective skills instruction is presently an open question. One possibility is to provide the pupil or parent with the option concerning whether given instruction in elective skills should yield mastery or--like certain survey courses--no more than familiarity with the domain. If such an option is exercised on a skill-by-skill basis in the elective domain, then the diverse desires of pupils and parents, and of a society such as the current one, would probably be better served than if exercise of one or the other option was meant to apply universally. Whatever resolution of this matter the community affords should be reflected in pedagogical architecture.

The structure of any skills domain that is not of trivial complexity places constraints on how instruction will be scheduled across elements or subskills of the structure. Most skills domains do not compel negotiation of the structure according to a single most effective progression. One of the most important requirements placed on the architect of pedagogical systems is that the architectural product reflect only those progressions through skills domains that will insure eventual mastery of domain terminal skills. There are no good names for this high art, although such terms as skills analysis and hierarchicalization are used from time to time to refer to it. The art has been practiced at an intuitive level since antiquity. The requirements that stem from a mastery view of the educational process compel explication of the art and the marshalling of empirical evidence and rational arguments that support the scheduling routines manifest in pedagogical architecture. Although slowly, the tendency of educational R&D is to move in that direction. We hear less than we used to of a logical or a priori basis as the only basis for scheduling instruction within a skills domain.

Scheduling to meet sufficiency conditions for skills mastery gets at instructional effectiveness. Scheduling to meet necessity-sufficiency conditions gets at instructional efficiency. If there are alternative effective instructional paths through a given skills domain, then some of these paths may lead the pupil to skills mastery sooner or at less instructional cost than others. While effectiveness issues have not attracted much empirical interest, efficiency questions have long appealed to the behavior scientists. Tendencies toward individualizing instruction address both effectiveness and efficiency issues. Given that instruction is individualized or made suitably interactive, there is much that can be done to improve instructional efficiency. Such characteristics of drill routines as display time, amount of repetition, and size of the contrast set all must be given concrete expression in the pedagogical architecture. There is a growing interest among academy personnel in referencing work on such factors to the educational situation or reasonable facsimiles thereof. Current trends warrant the view that pedagogical architectures five or ten years hence will reflect state-of-the-art efficiency levels that result from application of explicit and quantitative theories of limited scope.

A decade ago most of the concepts that follow from a criterion-referenced proficiency testing perspective were apprehended at the rhetorical level. The primary difference between then and now is that it was not then appreciated that educational R&D and its supporting sciences possessed the structure only at a rhetorical level. Bets have since been called and the gap between rhetoric and exploitable science and technology discovered. The trend now in sophisticated educational R&D is to manufacture the statistical rationale that criterion-referenced testing requires, to give suitably concrete meaning to such terms as remedial instruction, diagnosis, and prescription, to separate pedagogical system and information system implications of instruction that seeks to improve effectiveness-efficiency by better matching instruction to pupil characteristics, and to acknowledge that efficiency questions in particular will only be resolved beyond the capabilities of artistry when framed by theory and investigated within the theoretical frame. There has been other, more positive, progress, but the highlight of the last decade is one of shedding ignorance concerning the bounds of our ignorance. A fair bet is that the educational system designer of five or ten years hence will bring to the task of architecting pedagogical systems a well-worked-out criterion-referenced testing rationale, a well-worked-out rationale for matching instruction in form and explication to pupil characteristics, and some restricted theories that will guide efficiency optimization of the architecture. The result will be education that, in principle, is a good deal more effective-efficient than is currently achieved at the drawing board. To obtain these benefits in practice depends on information system characteristics, a matter to which we now turn.

Information Architecture

During the tutorial era that preceded mass education, the pedagogical architecture was for the most part loaded into the teacher's brain. The administrative hierarchy did not yet exist. Class size typically numbered one. The information architecture was a model of simplicity, involving teacher-pupil instructional and parent-teacher supervisory interfaces. Instruction was administered and performance was monitored and critiqued without intermediation; parental supervision was equally direct.

Mass education lowered teacher-pupil interaction while complicating the information architecture. Today's teacher typically enters into three classes of interfaces with pupils: 25 or more one-on-one interfaces, three tracking interfaces--e.g., one-on-reading-group, and one class or general lecture interface--one-on-class. This situation can be made more equitable through the use of aides and student "teacher-pupil" routines appropriate to certain forms of drill. However, from the pupil's standpoint, much of the instructional day is interactively zero-on-one. The conscientious teacher of mass education is quite busy relative to the teacher of tutorial times; the pupil either much less so or on his own for appreciable periods of time.

The parent-teacher supervisory interface of tutorial times has been replaced by a complex chain. The mass education parent is required to commission a remote state apparatus and a school board that typically is only slightly less remote to supervise the teacher through the intermediation of a district superintendent, a principal, and a scattering of supervisory personnel. This organization for supervision by indirection attenuates supervision even further through adherence to the doctrine of sanctity of the classroom from prying eyes, particularly those of the parent and of other interested individuals not connected with the school system. Whereas supervision in tutorial times was directly based on parental self-interest, today's supervision is a more-abstract mechanism that is responsive only to well-organized and widespread parental disaffection. In tutorial times, the parent had direct access to the teacher. In mass education, there really is no socially acceptable access to the teacher except in the contrived PTA situation--organized parents typically target on the district superintendent. Hence, although almost as numerous as sparrows, teachers--like the bald eagle--have become a protected species. This protection could well be specious, since carrier pigeons also once were almost as numerous as sparrows.

There are alternative ways to view the functions of an information architecture. One approach envisions the minimally interactive instructional situation that could be installed in today's schools without abandoning the prevailing teacher-class organizing scheme. This approach would insure in practice that a pedagogical architecture predicated on the prevailing teacher-class form of organization is as instructionally effective-efficient as the design of such architecture makes it in principle. Shorter-term efforts to design information architecture probably will feature this approach for two compelling reasons: a) An alternative approach would encounter staggering installation costs. b) We do not yet know in what degree and under what conditions interactive instruction will enjoy an operationally productive edge over other forms. This we call the shorter-term approach to architecting the information system. An alternative approach envisions an empirically-justified higher level of interactive instruction. It would insure in practice that a pedagogical architecture predicated on a reasonable per pupil hour cost of instruction--e.g., 80-85 cents--is as instructionally effective-efficient as the design of such architecture makes it in principle. What drops out here is any commitment to current forms of organization and ways of doing business. This we call the longer-term approach to architecting the information system.

Before taking up trends and possibilities associated with shorter-term and longer-term approaches to architecting information systems, it needs to be emphasized that the implied timing does not sacrifice a wondrous technology of interactive instruction that, currently lying on the shelf, cries out to be exploited. Experience to date suggests that interactive instructional productivity will depend to a degree on pupil characteristics (e.g., prior achievement levels relative to national averages), teacher proficiencies, or both (cf, Jamison, Fletcher, Suppes, & Atkinson, 1971). Jamison et al. present data that supports the view that essentially computer-delivered instruction that is rationed to children at the rate of 10-15 minutes per pupil per day could by 1975 be obtained at a cost of $2 per pupil hour--somewhat over twice the cost of prevailing group instruction. Moreover, only when such instruction is compensatory (i.e., when prior achievement levels are well below national averages) will it enjoy a cost-benefit edge over teacher-delivered compensatory education. It remains to be established that interactive instruction will be equally productive across all skills domains or regions within these domains. It remains to be established just how interactive interactive instruction must be to be a productive alternative to group instruction; hopefully, we will not need to join the earlier programmed learning investigators in asking that an instructional management decision be predicated on a response to every tiny bit of instruction fed to every pupil throughout the instructional day. While intuition and a small but growing body of careful research suggests that pedagogical architectures will give prominent sway to interactive instruction a decade hence, the unanswered questions suggest a research effort that well may use up most of the decade. It appears warranted that we should reserve shelf space for the fruits of such research. However, little is on the shelf now except hope, which is unexploitable.

Consider a given skills domain as instructionally treated by one or more year-long courses of instruction using 25-50 minutes per day of instructional time. If we divide any such year-long course into 10-12 consecutive *units* of instruction, then unit-level criterion-referenced proficiency tests either have been or could be constructed in rather short order covering all of the academic skills domains that are currently relevant to the K-6 schooling years.

Two alternative approaches to shorter-term efforts to architect information systems are considered below. The first assumes prevailing class organization wherein pupils constitute a heterogeneous or diverse proficiency group (DPG), some 30 in number. The second assumes a 30-member class, but one that encompasses three rather homogeneous proficiency groups (HPG) per skills domain (or per year-long course), with reconstitution of the HPG a possibility quarterly on the basis of unit test performance during the quarter.

DPG type architecting of information systems might proceed from the following assumptions: a) Unit tests exist for all year-long sequences of instruction for the primary school years. b) These tests are neither diagnostic nor prescriptive. c) The pedagogical architecture provides alternative supplemental instructional treatments and appropriate organizational advice which the teacher can use as a resource when assigning supplemental instruction for a pupil who fails to reach criterion proficiency when unit tested following initial instruction.

Before continuing we need emphasize that the view of an information system that is adopted here is a broad one that encompasses both the instructional system and the supervisory system. Particularly when one contemplates the eventual rise in interactive instruction and in the automation of facets of instruction, it becomes apparent that the view of an information system as a limited support and monitoring device referencing to an instructional system is a special case, however appropriate to the prevailing organization of instruction. If a pedagogical architecture insures realization in principle of educational system functions, then a man-machine mix either does or does not guarantee in practice theoretical expectations inherent in the pedagogical architecture. It is useful to distinguish between instructional and supervisory interfaces and perhaps also useful to distinguish between people and machine components of interfaces. However, shorter-term and longer-term programs considered together, it appears more useful to view the information system as generic to education (or any other enterprise) than as a component of a generic system. For the school system is a network of channels over which information is transmitted and received. Those who design such systems seek to insure that relevance and efficiency are state-of-the-art optimized. Subsystems of the information system are the instructional and supervisory systems, appropriately housed; subsystems of these are man-machine systems that do particular things, such as score tests, select next instruction according to prespecified criteria, and report progress.

One almost always erects the new on the old. Let the new pedagogical and informational architectures be in design form until installed; they will replace old pedagogical and informational architectures in place in the schools at the outset of installation. The transformation from old to new must of course begin with a decision to make the change. This decision endorses the instructional and control provisions of the new pedagogical architecture and the modification implications of the associated new informational architecture. The design of the new information architecture specifies how the existing information architecture will be modified to accept the new pedagogical architecture. That is, it specifies how instructional personnel will be retrained to administer and manage a new instructional program, how supervisory personnel will be retrained to monitor and control the new instructional effort, and how equipment and housing will be augmented or modified to permit administration-management and monitoring-control of the new instructional program. Installation, then, consists of modifying an old information architecture to accept a new pedagogical architecture. This it does by creating a new information architecture that is consonant with provisions of the new pedagogical architecture.

In prevailing school systems, the teacher is the primary component of the instructional facet of the information system. State and district mandate in broad outline the relevant skills domains and amount of coverage in instructional hours or years of group instruction. Mandates on proficiency are hazy at best. Norm-referenced proficiency testing is assumed. While this arrangement does not preclude the accretion of information over the years on which to base teacher evaluations for instructional effectiveness-efficiency, only the teacher who is a social freak or who chronically disregards administrative directives can fail in the shorter-term.

DPG information architecture would change the prevailing situation by pumping criterion-referenced testing information into the supervisory system and, in appropriate form, to parents on a periodic basis. This information would be obtained from unit tests administerd 10-12 times per year per skills domain. For example, the record might begin with either an entry or first-unit test score for each pupil in the class for each skills domain subsumed in the curriculum. This record might be updated following tests on each succeeding unit. Advice to teachers concerning alternative supplemental instructional treatments would occur in the pedagogical architecture. However, the architecture would reflect neither diagnostic nor prescriptive statements, and the teacher would be free either to treat the data as one would treat norm-referenced test data or to organize the class consonant with minimizing instructional advance in absence of mastery of skills taught in earlier units. While the second choice would be the wiser one in light of the fact that such information will be fed into the supervisory-administrative system (which now receives no information on proficiency that is substantive rather than judgmental), it is a difficult choice to make because it asks the teacher to use great personal ingenuity to overcome the conflict between one-many organization and the more individualized organization that is implied by class heterogeneity--which should lead to differential instructional time to mastery of unit skills. The DPG information architecture affects the teacher only by imposing unit criterion-referenced tests on the instructional system, transmitting records of such tests outside the instructional system (to the supervisory-administrative system and parents), and by introducing the teacher to a new pedagogical architecture which *may* offer advice on how to transform the one-many organization into a more individualized organization that still is one-many in generic form.

The DPG information architecture represents a more-substantial modification of the supervisory-administrative system. To achieve its supervisory function, the DPG information architecture must insure that accurate test records leave the classroom on a per pupil per unit per skills domain basis, that these records are analyzed and the information suitably characterized--e.g., as class distributions or class mean-SD statistics--for supervisory purposes, that performance characterizations are suitably interpreted in reports written for supervisory purposes in school and home, and that the reports are transmitted on a timely basis to supervisory-administrative audiences. Moreover, the DPG architecture should be able to do all this at a cost on the order of 25 cents per pupil per unit per skills domain (which is on the order of two percent of the annual per pupil cost of instruction). This requirement suggests an automated system having data concentrator, analysis, and report-writing features that is accessed through a source data automation device located in the classroom or the school. Such systems are under development at the present time. The principal challenges to obtaining such systems reference to the terminal device, which must be sufficiently versatile to preclude compromising intent of the criterion-referenced proficiency test, and software that is consonant with report-writing provisions.

The homogeneous proficiency group (HPG) is a notion introduced by Kriewall (1969) as a compromise between prevailing one-many instruction and individualized instruction. There are various ways to exploit the HPG; we will consider the least-powerful of these alternatives here. The one-many organization is retained as the outer shell of the HPG information architecture in this case, and it reduces to a multitracking scheme, but not of the usual sort. Let us imagine that the school is a primary school, the class consists of 25-30 pupils, and that the curriculum subsumes six skills domains. Moreover, let Unit 1 test performance be the basis for assigning pupils to HPGs in each of the six skills domains. Let number of HPGs per skills domain average 3, with range 2-4. HPG type information system architecting might then proceed from the following assumptions: a) Unit tests exist for each of the six year-long sequences of instruction. b) This mainline instruction is no more extensive than is required to occupy the pupils of the slowest HPGs for three-quarters of the school year; elective instructional options are sufficiently extensive to occupy the pupils of the fastest HPGs during all of the school year that remains after they have mastered the mainline instruction. c) Unit tests are diagnostic in that the different elements or subtests of these tests refer to different elements or subskills of the unit portion of the skills domain. d) Mainline instruction is not prescriptive; however, the pedagogical architecture makes available to the teacher alternative supplemental instructional treatments that can be used when a pupil tested following initial instruction fails to reach criterion proficiency. Information architecture of the HPG type seeks to help the teacher to implement a decision to make instructional advance contingent upon mastery of skills instructed in prior units by a) providing a grouping basis that somewhat precludes the need for individualization of instruction, b) providing elective filler that obviates the necessity for attending to the needs of slower pupils at the expense of faster pupils, c) grouping on the more-apt basis of performance referencing to specified skills domains rather than on the inapt basis of a characterization for general intelligence, d) providing a diagnostic basis for selecting supplemental instruction, and e) making available the option of reconstituting HPGs periodically throughout the school year on the basis of changes in test-defined rate predispositions. This last can most easily be effected by dividing up the school year for purposes of mainline instruction--e.g., into

Units 2-3, 4-6, 7-9, 10-12--with elective filler instruction as needed interspersed with mainline coverage. This scheme would permit reconstitution of HPGs following testing of Units 3, 6, and 9 in each skills domain.

The HPG information architecture would have all of the same supervisory functions as the DPG information architecture. It would handle the same volume of test data and make all of the same reports to supervisers. However, unlike DPG, HPG information architecture would pick up teacher assistance functions for instructional management. Its new functions would be to score tests more finely consonant with diagnostic provisions by HPG, to report its diagnostic findings to the teacher with scant delay, and to assist the teacher in HPG formation and regrouping. It might also periodically offer advice on supplemental instructional options. However, much of this advice would carry the architecture beyond the shorter-term time frame and into that of longer-term individualized interactive instruction. The details of the functions to be addressed by the HPG information architecture would appear in an HPG pedagogical architecture. The challenges underlying development of HPG information architectures should occur in the same domains as those underlying DPG information architecture development--those of terminals and computer software. However, whereas the DPG terminal needs to be interactive only to permit the central system to access test records on an effective-efficient basis, the HPG terminal must give the teacher better access to the central system.

No doubt, information architectures of the longer-term will be prescriptive as well as diagnostic, will be more interactive than "once a month" per class per skills domain, will be more-directly predicated on the notion of individualized instruction, and will be automated to the full extent of our understanding of the relevant pedagogy and capability for achieving automation on a productive basis. The fine-grained computer management of mainline instruction, accompanied by a broader-brush computer management of elective instruction, is a possibility a decade or two hence. By then, cable television will be available to school and home, communication between school and central computer via satellite will be possible, and, if we begin making the right efforts now, terminal systems will be available that can act in a quasi-independent manner throughout all or an appreciable portion of the instructional day (thus obviating the need for tying up the central computer on a continuing basis). Noted earlier, research will have to substantiate the degree to which individualized interactive instruction will pay off and show the skills domains and regions in which it will pay off. This research will affect pedagogical architectures in the longer term. We will have to anticipate some features of the findings from such research if we want to avoid serial development that defers design and development of terminal systems until pedagogical architectures of the longer term are set.

Site Architecture

There is a growing feeling--cf, Coleman (1972)--that schooling at its best can only deal effectively-efficiently with a portion of the skills that are relevant to one's functioning as an effective young adult. Coleman views the academic skills of schooling as only one component--although major to be sure--of an *extended education*, occurring across multiple sites in the community, that exhausts all of the skills domains that are relevant to effectively functioning young adulthood. While it is probable that multiple-site education will occur to a much greater extent during secondary school years than during primary school years, pedagogical and information architectures eventually will have to respond to the multiple-site view of extended education.

Parker & Dunn (1972) note that cable television will reach the home--and so could reach any other site--to an appreciable extent by the early 1980s. They argue that the potential of this development for serving education will not be realized if we do not now begin considering the sorts of home terminal equipment that will be needed to exploit cable television for educational purposes. It appears possible that such equipment would have something in common with that which one would develop to serve longer-term information architectural needs of the schools. One could, of course, assume that the home will supplant the school as the locus of academic education on entry of cable television as a near-universal characteristic of homes. A more likely possibility is that home instruction via cable television will only supplement schooling in the shorter-term longer term. However, cable television well may represent the technical breakthrough we need to promote extensive *continuing education* of adults. Continuing education is old in concept and modest in practice. If Brzezinski (1970) is correct, then a) the workforce will by the early 1980s be appreciably in occupations that are knowledge system-exploitative, b) there will be a staggering technical compulsion to upgrade skills within occupations on a periodic basis, and c) there will be a compelling psychological basis for changing occupations after 15-20 years of doing a given thing. If the demand for college-level continuing education expands in consonance with Brzezinski's views, then a cable television capability for providing education in the home cannot come a minute too soon.

Pedagogical architectures will specify the work that information architectures will be created to perform. As pedagogical architectures increasingly reflect multiple-site housing architectures that are consonant with extended and continuing education, information architectures will have to follow suit. Multiple-site education probably introduces no new characteristics that terminals must have in the longer term. However, such education does introduce networking and channel-selection problems that promise to be more complex than when handled in the context of one site or one kind of site.

EDUCATIONAL SYSTEM SPECIFICATIONS

An education system (ES) may be considered to have an architecture (EA) that defines its internal structures and a set of input-output functions (EF) that are consonant with and consequences of its structure and that link the system to an external environment. The objective of any R&D effort to construct an educational system is to produce an educational architecture that will more effectively and efficiently instill in the child types and levels of proficiency serving the relevance requirements of society. An R&D effort achieves this objective by removing ES options when this is in order, by defining apt alternative ES behaviors when this is in order, and by capitalizing on the teacher as a professional operating beyond the prevailing boundaries of science and technology when this is in order.

Form and operating characteristics of a specified new ES will be a consequence of many factors. These factors refer either to *system specifications* or to *states-of-the-art* that condition realization of system specifications. The system specification headings apparently are a) perceived market constraints regarding ES costs--or *cost bounds* (CB)--and b) perceived market constraints regarding ES relevance functions--or *relevance bounds* (RB). Cost and relevance bounds determine what we will ask a specified new ES to do and under what conditions of costs referenced to system utilization. Broader-brush specifications of states-of-the-art for instructional effectiveness and efficiency underlie evaluation of *feasibility* of ES as envisioned by CB and RB specifications. Cost and relevance bounds are discussed below; feasibility evaluation in the section that follows.

Cost Bounds

Market constraints on costs of developing, installing, and operating ES are expressed as cost bounds. What one will pay to design, develop, install, and operate a new ES depends on the extent to which it is more relevant, effective, or efficient than a prevailing ES. CB specifications probably should speak to system operating life, time of installation, cost per pupil hour of instruction, and total number of pupils to be served. A new ES must be cheaper, more relevant in its mainline instructional outcomes, more effective, more efficient, or a combination of these than is a prevailing system that it is designed to supplant.

Development-installation costs of prevailing instruction are not known. However, the contemporary K-6 pupil averages something like 1080 hours per year in the classroom and in supervised playground activities at an average annual cost of something like $900 per year--or 80-85 cents per pupil hour. Prevailing instruction is not always effective and, when effective, typically is less cost-return efficient than appears state-of-the-art optimal. Many feel that prevailing instruction is not optimally relevant regarding objectives of instruction. CB specifications will reveal a marketable new ES only to the extent that design-development costs are reasonable, installation and operating costs are bearable, and relevance, effectiveness, or efficiency--or a combination of these--is superior to that that prevails.

Relevance Bounds

The relevance bounds imposed by market constraints refer to scope of mainline instruction and to proficiency levels for terminal skills. The RB specification effort will delete some outcomes that schools, for one reason or another, now attempt to produce but never will teach well in the school setting. The effort will redefine other outcomes by deleting traditional but academically (and motivationally) irrelevant components and broadening or deepening coverage of more-central components. It will add other outcomes--e.g., facility with computer languages--that recent technical advances require the pupil to be proficient in prerequisitely to becoming a modern problem-solver.

If we distinguish between mainline instructional outcomes that are bounded by an apt scope and elective instructional outcomes that may be acquired by pupils when not engaged in mainline instruction, then we can probably be rather relaxed concerning proficiency levels for the elective areas. The setting of terminal proficiency levels is an earnest probelm only for mainline instruction. Perhaps it is not so earnest a problem as is sometimes imagined. Essentially, the RB specification effort has to decide whether a mainline instructional sequence should culminate on longer-term mastery or longer-term familiarity short of mastery. Thus, such an effort might specify longer-term mastery for such skills as reading the front page of a newspaper or contents of employment bulletins addressing the young adult population in general, solving everyday economic problems, making a case for oneself, rendering biosocial first-aid, and performing library research to serve a variety of young adult needs. It might specify less-proficient levels--fewer items of retention--for world political geography, the fine arts, and higher mathematics. Specification of proficiency levels for those portions of skills progressions that are preterminal stem from effectiveness-efficiency considerations, rather than those of relevance. Hence, the RB effort would not address preterminal.proficiencies.

Consequences of Cost and Relevance Bounds

Cost and relevance bounds are constraints upon design of the educational system. If we add posited entry levels to relevance bounds, then CB and RB specifications tell us in general terms what the system must do at what cost. RB specifications then state what distances must be negotiated along what skills progressions and so deal with effectiveness and relevance functions of the desired ES. CB specifications implicate efficiency functions of ES by stating at what cost RB distances will be negotiated. The R&D effort to construct a new ES is justified if system specifications promise a more productive ES than that which prevails and if the promised system is feasible in light of state-of-the-art. Feasible system specifications specify a set of input-output functions for ES--an EF set--for which there exists at least one system architecture--EA--that is congruent with both cost bounds and state-of-the-art.

FEASIBILITY OF SYSTEM SPECIFICATIONS

While they seem destined to come together eventually, effectiveness and efficiency states-of-the-art have somewhat different origins and current identities. Behavior scientists have long assumed that instruction addressing effective acquisition is no particular problem and have pursued efficiency questions predicated on a priori views of instructional effectiveness. Efforts to make an educational system effective will be temporally prior to those addressing system efficiency.

At a broader-brush level, instruction is effective in principle if one can show that the journey from posited entry levels to specified terminal outcomes can, in effect, be made by entering pupils. Techniques such as skills analysis-predicated on notions of logical continuity, stages of logical maturation, seriation-integration of skills, and instructional spiraling--yield schemas reflecting state-of-the-art posited skills progressions. When seeking to establish feasibility of system specifications in light of state-of-the-art for effectiveness pedagogy, one will be uninterested in the finer-grain aspects of the problem of specifying effective skills progressions. Rather, the object of such effort is to reach a decision concerning whether system specifications are feasible in light of effectiveness state-of-the-art. If system specifications are feasible on this score, then an R&D effort to design and develop the implicated ES will be found timely. Otherwise, preliminary schemas will need to be used to determine the directions in which state-of-the-art must be pushed before such an R&D effort would be justified.

Instruction is efficient in principle if efficiency state-of-the-art shows how the journeys from posited entry levels to specified terminal outcomes can be made consonant with cost bounds. The object is to reach a decision concerning whether system specifications are feasible in light of efficiency state-of-the-art. Again the possibilities are "yes" and "no", with "no" the signal to determine the directions in which state-of-the-art must be pushed before a contemplated R&D effort will be justified.

Potential new educational systems addressing shorter-term installation will be evaluated for feasibility conditional on states-of-the-art that are consonant with the DPG and HPG information architectures discussed earlier. Immediate R&D efforts probably will feature DPG information architectures to minimize start-up costs and because there presently are holes in the pedagogical state-of-the-art that must be plugged before alternative architectures become feasible. As start-up costs come down due to technical advance and increasing demands generated by advances in pedagogical state-of-the-art, R&D efforts predicated on HPG information architectures will become feasible; such efforts are near-feasible now. Efforts predicated on the more-sophisticated information architectures required to deliver extensively individualized interactive instruction will occur only when the associated pedagogy has been created and found suitably productive. Such efforts are not remote; we can see their broad outlines already. However, development and installation of educational systems that feature appreciably interactive instruction will probably neither address comprehensive systems nor attract extensive expenditures during the years immediately ahead.

PHASES OF AN R&D EFFORT

The educational R&D enterprise or organization exists periodically to contribute a new ES that is functionally superior to a prevailing ES. New ESs cannot be expected to appear with the frequency of Detroit hardware. Changeover to a new model is too costly to be warranted solely on the basis of cosmetic advances. Moreover, comprehensive new models take a good deal of time to develop, market, and install. Finally, the outline of a new ES does not reach apotheosis in consequence of a blinding, instantaneous vision, but rather in consequence of appreciable efforts to reduce uncertainty in the pedagogical and allied states-of-the-art. In consequence, the educational R&D organization is not simply a factory that produces new ESs. Rather, it is like a modern corporation that engages in a variety of R&D efforts aimed at divining characteristics of superior new products that, when found, it seeks to produce. Let us imagine that 15 percent of the organization's effort is devoted to the pursuit of potential follow-on ESs and 85 percent to the design, development, and installation of one or more ESs that are functionally and/or cost-return superior to prevailing counterparts and state-of-the-art feasible. If we add the provision that an ES under development be comprehensive--e.g., address the gamut of the K-6 schooling skills domains--then it can be safely assumed that a preponderance of the development effort will be devoted to a single new ES, with successive finished ESs becoming candidates for installation every five years or so.

The educational R&D organization having the general objective of producing and installing new ESs will feature work that references to different time frames and projected completion dates and that is in different phases of execution. We discern five phases of execution of effort: preliminary design, product design, effectiveness development, efficiency development, and installation. In addition, efforts referencing to pedagogical architecture--which secures specified system effectiveness-efficiency in principle--and to informational architecture--which secures these theoretical characteristics of the system in practice--are distinguished across phases because many aspects of efforts referencing to information architecture are conditional on form and functioning of pedagogical architecture. It will tend to be the case that most of the diversity of an organizational effort will be reflected in its preliminary design projects. Work in all later phases of execution will have gotten beyond the feasibility hurdle and a decision to see such work through to installation will have been made. (All such decisions are, of course, revocable on compelling new evidence.) In consequence, we may view work in the preliminary design phase as encompassing a wide range of potential follow-ons to existing efforts to produce and install new ESs, with each of the other phases concerned with a single ES at a given point in time. The second through fifth phases might be viewed as encompassing an ES that is in advanced production, with installation scheduled for Time X, and a firmed-up follow-on ES in preliminary production, with installation tentatively scheduled for Time X plus five years.

A *preliminary design phase* would pursue activities of the sort described in the previous section. A given preliminary design phase effort would reference to a specified production-installation time frame and would be bounded by the educational model--DPG, HPG, or individualized interactive instructional--that is appropriate to that time frame. The effort would specify cost and relevance bounds for an envisioned ES and establish feasibility of the envisioned system. The feasibility test passed, the envisioned ES would become a candidate for a large-scale production effort. Otherwise, the effort should cause state-of-the-art to be pushed consonant with a later attempt to render the envisioned system feasible. The effect might be that directed advances in state-of-the-art succeed in their purpose, rendering the envisioned system feasible. Alternatively, any such advances might prove insufficient, signalling a need to abandon the envisioned ES or to modify it regarding functions or time frame. All the while, new technical and conceptual advances in a larger context would be occurring, with implications for the range of envisioned ESs being explored at the preliminary design level.

In a given preliminary design program, one might expect to find differently time-framed efforts addressing the DPG, HPG, and individualized interactive instructional models sketched above. Some of these efforts might span entire educational architectures, while others addressed only the pedagogical or informational architecture or facets thereof. Not all of these efforts would be equally advanced. Given the present state-of-the-art, efforts referenced to the prediagnostic DPG model would be furthest along, those referenced to the preprescriptive HPG model next furthest along, and those referenced to a postprescriptive individualized interactive model least advanced. Efforts associated with an individualized interactive effort might deal with the larger issues of multiple-site extended education and continuing education in the home.

The foregoing view of one organization's preliminary design phase efforts does not argue that a single organization will mirror the entire range of activities subsumed by the educational R&D enterprise. Rather, it asserts that *conceptual* effort is the cheapest commodity that the nation can obtain from any such enterprise. All organizations can and should contribute to the conceptual effort. There is enough such action to go around, and this promises to continue true indefinitely. Only when such work reveals extensive requirements to push state-of-the-art will it become important to specialize workforces to reduce overlapping effort.

A *product design phase* of ES production would take as input cost and relevance bounds specified and found feasible during a preliminary design phase for a given ES that the organization believes represents its best follow-on alternative. The principal objective of the product design phase would be to schedule work during development phases. This schedule would reflect conditional relations known to hold between certain components of the system to be constructed. The distinguishable efforts that would be made during an *efficiency development phase* typically should be conditional on prior efforts made during an *effectiveness development phase*. Within phases, efforts addressing informational architecture typically should be conditional on prior efforts addressing pedagogical architecture. Efforts addressing installation of the new system typically should be conditional on prior efforts addressing information architecture, because the installation process involves transforming a prevailing informational architecture into a new one that is consonant with the new pedagogical architecture.

Effectiveness development addresses both pedagogical and informational components of system architecture and may be broken down into a number of steps, with execution of some of these steps conditional on completion of earlier ones. Thus, specification of skills progressions in fine detail will precede development of criterion-referenced proficiency tests. (Some believe the reverse.) The pursuit of alternative supplemental instructional strategies is somewhat conditional on one's view of initial instruction. (Extent of a commitment to alternative instructional strategies depends on the controlling educational model. DPG models will not accommodate to alternative strategies as readily as HPG models, which in turn will not do so as readily as more-individualized interactive instructional models.)

Structure of the efficiency development phase will be crucially dependent on the educational model selected--DPG, HPG, or individualized interactive. Outputs of the effectiveness development phase--particularly those for skills progressions and CRTs--will condition much of the work that is done to improve system efficiency in the sense of conserving instructional time. Some of the gains envisioned by this phase will involve changing the man-machine mix of the instructional system consonant with doing things more quickly, unerringly, or cheaply.

The product design phase will produce schedules for the effectiveness and efficiency development phases that are consonant with the contingencies preliminarily sketched above. Effort during the product design phase will also extend to the structuring of system installation. All scheduling efforts of this phase will seek to achieve desired product characteristics while holding time to installation to a minimum value.

The decision to staff a product design phase is a rather firm commitment to construct and install the system, subject only to the organization being overtaken by compelling reasons why the contemplated system should be abandoned or recast. A possible organizational approach would be to form management team to oversee all work on the system beginning with staffing of the product design phase and culminating with completion of the installation phase or a prior decision to abandon the system.

CONCLUDING NOTE

We have no recourse to accepting one of two alternative educational futures. The first might be called the laissez-faire future. On the surface, such a future is the one we obtain by sitting back to await the effects of diverse forces interacting in a free market. Unfortunately, this view of a laissez-faire future is illusory. It spawns amusement opiation where we could have educational cable television and protectionist academic freedom where we could have education that is responsive to the needs of parents and a larger society. A laissez-faire educational future will be one wherein post facto analysis will reveal that some pigs in the market were more equal than others, which might be good news for TelePrompter but would be bad news for most everyone else. The alternative to a laissez-faire educational future is that which society can obtain tomorrow by commissioning its responsive agents to get to work on the problem today. This is the future one obtains by broadening the horizons of the educational system designer to transcend products ~ready conceptually frozen in most respects. Such broadening trans.orms the work of conceptualizing tomorrow's progression of futures into today's myriad efforts of a preliminary design nature. Tomorrow's realities will be a consequence of today's efforts. The critical question is "Who will make these efforts?" Who would one have more confidence in than oneself?

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